Earthquake vulnerability assessment using GIS and high resolution satellite imagery

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Motivation — Earthquake May 2006

The island of Java (Indonesia) was hit by a major earthquake on 27th of May 2006. According to the USGS* the epicenter was located south of Yogyakarta City (see Fig. 1). The earthquake caused widespread damage and a high number of casualties along the Opak fault. This revealed the necessity of vulnerability assessment within this region. An area of 40 km^2 within the district of Bantul was chosen as the study area for an earthquake vulnerability assessment approach based on geographic information systems and high resolution satellite imagery.

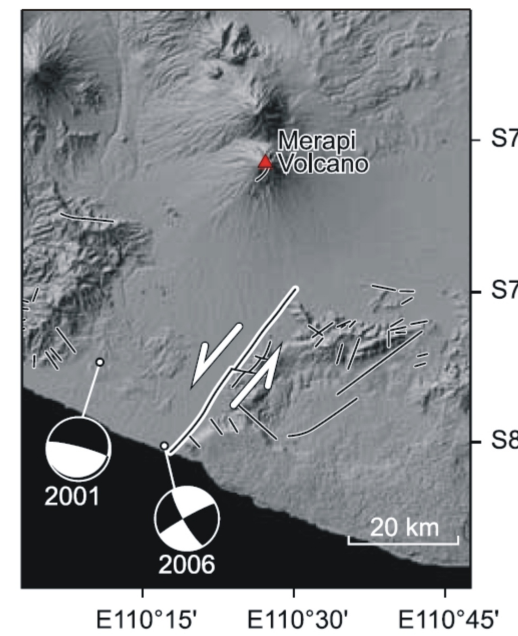

Fig.1: The Opak fault and the epicenter of May 2006 Earthquake

Tectonic Setting — Island Java

The tectonics of Java are dominated by the subduction of the Australia plate north-northeastward beneath the Sunda plate with a relative velocity of 6 to 15 cm/ year (Stüben,2006). The hypocenter for the May 2006 earthquake was located at shallow depth < 30 km (Brüstle et al.,2007). Setijadji (2007) suggests that the ruptured fault is a reactivated, tertiary fault parallel to the Opak fault.

Methodology — Indicator Development

The formulation of goals is the first step in risk modeling. The goals serve as starting points to identify important factors. Four physical factors could be identified that contribute to earthquake risk: geology, environment, climate and topography. For each factor representing indicators were developed (s. Fig. 2). In the next step a hazard specific weight was assigned. Therefore each indicator was classified and each class was weighted according to its importance to the indicator I_1. Than the indicators were weighted I_2 according their importance relative for the indicator they represent. The weight I_3 was assigned by weighting the factors relative to each other. The susceptibility for each grid cell of the study area was given by the sum of the susceptibility of each indicators. The results were display on a susceptibility map (s. Fig. 3). The distribution shows the significance of the subsurface. The wide distribution of the sediments of the Sleman and the Yogyakarta Formation can be directly correlated with the high ratio of the susceptibility class *maximum*, which comprises more than 50 % of the study area.

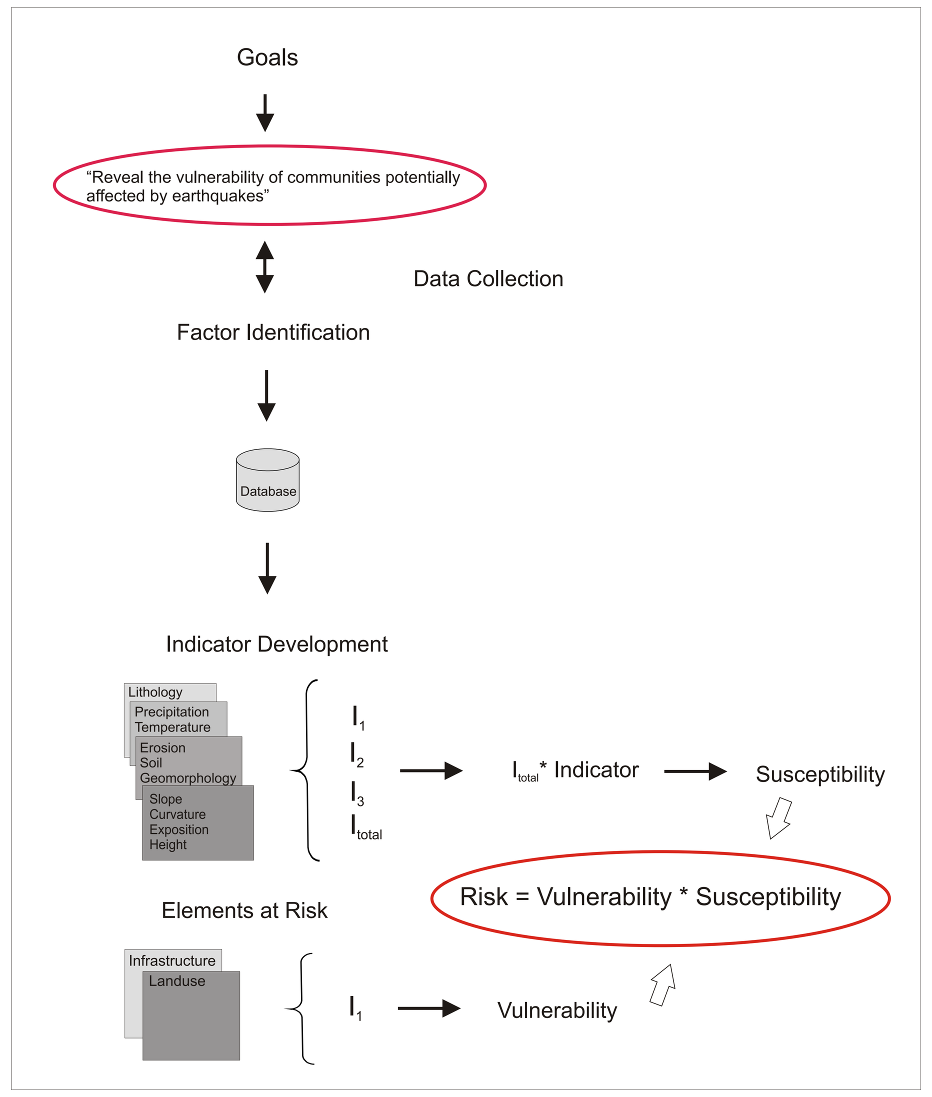

Fig.2: Workflow scheme for GIS-based risk assessment

Stüben(2006): Erschließung und Bewirtschaftung unterirdischer Karstfließgewässer in Mitteljava, Indonesien. BMBF-Report.
Brüstle et al. (2007): Erdbebenschäden bei Yogyakarta. DGEB
Setijadji(2007): Interpretation on the setting of the Yogyakarta earthquake 2006 (central Java, Indonesia) based on intergration of aftershock monitonring and existing geological, geophysical and remote sensing data. EOS Trans. AGU, 88(23)
*Http://earthquake.usgs.gov/eqcenter/recenteqsww/Quakes/usneb6.php

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Methodology — Object oriented image analysis

The quality of the model depends directly on the quality of the input data. Therefore an object oriented image analysis was conducted using very high resolution satellite image (Quickbird). Using the software package Definiens Developer 7 a segmentation and a classification procedure was developed to extract information on land use and infrastructure. For the segmentation a multiresolution approach was used in order to consider objects of interest at different scales, e.g. land use units on a larger scale than single trees. The obtained classification can be exported as ArcGIS compatible format and used as input data for the model. This is a big advantage since the model was developed using ArcGIS 9.2 model builder.

Application — Vulnerabiltiy and Risk Modeling

The vulnerability of an area depends on the inventory of the study area, so called elements at risk. The following elements were considered: physical infrastructure, population density and land use. For modeling purposes all data were converted to raster data set. The different exposure layers were combined and the vulnerability was classified into five classes. The results were displayed on a vulnerability map (Fig. 3). The risk map was generated by a linear combination of the susceptibility and vulnerability map.

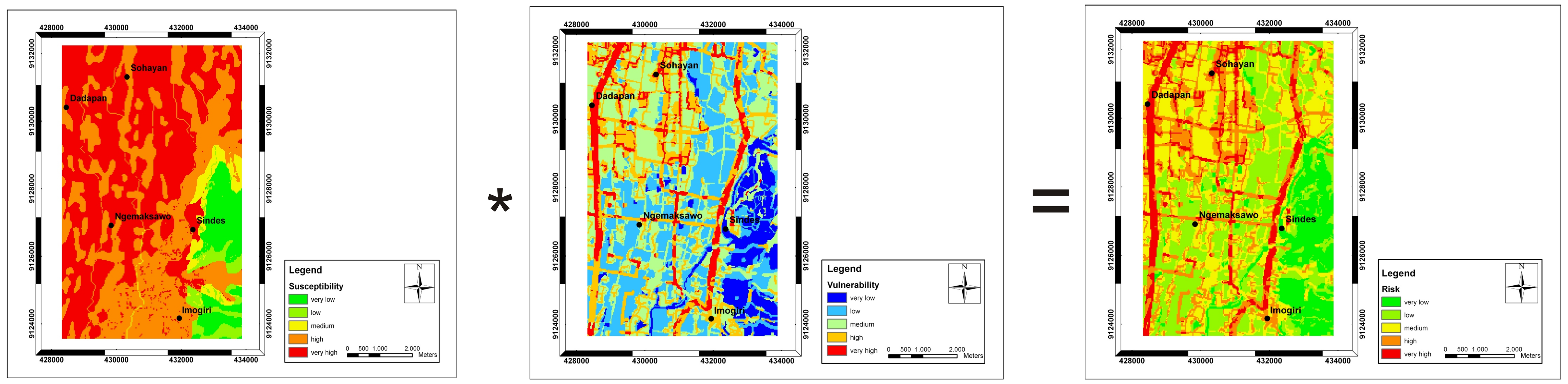

Fig. 3: Susceptibility-, Vulnerability- and Risk-Map (left to right). The multiplication of the susceptibility and the vulnerability of the study area results in the final risk map of the study area.

Conclusions

The numeric assessment approach based on expert knowledge and hazard specific indicators proved to be suitable to be used in areas prone to earthquakes. The risk map mirrors quite well the damage distribution reported by different NGOs for the May 2006 earthquake. A direct comparison with damage distribution has not been done yet, but offers an opportunity to adjust the indicator weights. The GIS implementation enables an automatic execution of the risk modeling procedure. This a convenient advantage which allows for the application of the model to different areas.
An improvement of the input data regarding the actuality and the accuracy due to the remote sensing analysis is

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GFZ Potsdam a Helmholtz Centre
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